CLAIMS

We claim:

1. A device for controlling fluid flow in a microchannel, comprising:

a mobile, monolithic polymer element disposed in the microchannel, wherein said mobile, monolithic polymer element is made by polymerizing a monomer mixture within the microchannel; and

means for providing a displacing force to control the movement of said polymer element in the microchannel.

2. The device of claim 1, wherein the displacing force is pressure or voltage.

3. The device of claim 1, further including spaced apart retaining means disposed within the microchannel and a bypass duct.

4. The device of claim 3, wherein said retaining means comprises a sealing surface.

5. A method for making a mobile, monolithic polymer element in a microchannel, comprising;

a) injecting a monomer mixture dissolved in a solvent into the microchannel, wherein the composition of the monomer mixture is such that the polymer formed by polymerizing the monomer does not bond to the microchannel wall;

b) polymerizing the monomer by application of radiation; and

c) flushing unpolymerized monomer mixture from the microchannel.

6. The method of claim 5, wherein the radiation is UV, visible, or infrared radiation.

7. A method for making a monolithic polymer element in a microchannel such

that the polymer element conforms to the configuration of the microchannel and does not bond to the microchannel wall, comprising the steps of:

preparing a monomer mixture comprising at least;

a cross-linking agents selected from the group including ethylene glycol diacrylate, diethylene glycol diacrylate, propylene glycol diacrylate, butanediol diacrylate, neopentyl glycol diacrylate, hexanediol diacrylate, pentaerythritol triacrylate, pentaerythritol tetracrylate, trimethylolpropane triacrylate,

a nonpolar monomer selected from the group branched or straight chain C_1-C_{12} alkyl acrylates, fluorinated or methacrylate versions of these monomers, or styrene, and

a monomer capable of carrying a charge at a pH of between about 2 and 12 selected from the group including C_1-C_{12} alkyl or aryl acrylates substituted with sulfonate, phosphate, boronate, carboxylate, amine, or ammonium;

adding the monomer mixture to a solvent, comprising at least;

one of the group including C_1-C_6 alcohols, C_4-C_8 ethers, C_3-C_6 esters, C_1-C_4 esters, C_1-C_4 carboxylic acids, methyl sulfoxide, sulfolane, or N-methyl pyrrolidone, dioxane, dioxolane, or acetronitrile, and

a polymerization initiator, wherein the monomer/solvent mixture forms a single phase mixture at a temperature below about 40 °C, and wherein the monomer to solvent ratio is between about 90:10 to 30:70;

loading the mixture into a capillary tube;

polymerizing the mixture by exposing at least a potion of the mixture to

radiation; and

flushing unpolymerized monomer from the microchannel.

8. The method of claim 7, wherein the portion of the monomer mixture exposed to radiation is defined by focusing a point or collimated source of radiation into the shape desired for polymerization.

9. The method of claim 7, wherein the portion of the monomer mixture exposed to radiation is defined by a mask.

10. The method of claim 7, wherein the radiation includes thermal, visible, or UV radiation, and wherein the wavelength of the UV radiation is equal to or greater than about 257 nm.

11. A mobile polymer monolith disposed in a microchannel and made by the method of claim 7.

12. A device for controlling fluid flow in a microchannel, comprising

a mobile monolithic polymer element disposed in the microchannel, wherein said polymer element is made by the method of claim 5;

at least one retaining means disposed in the microchannel; and

means for applying a displacing force to the either end of the microchannel.

13. A device for increasing fluid flow rates in a capillary, comprising:

a first and a second capillary joined together coaxially, wherein said first capillary has a larger diameter than said second capillary; and

a mobile monolithic polymer element disposed in said first capillary.

14. A device for amplifying fluid pressures in a capillary, comprising:

a first and a second capillary joined together coaxially, wherein said first capillary has a larger diameter than said second capillary; and

a mobile monolithic polymer element disposed in said first capillary, wherein said polymer element consists of a first and second coaxial segments, and wherein the second segment has a diameter adapted to fit within the second capillary.

15. A device for controlling fluid flow in a microchannel system, comprising:

a microchannel system disposed on a substrate, the microchannel system comprising a microchannel intersecting a cavity, wherein the cavity divides the intersecting microchannel into an inlet channel and an outlet channel; and

a rotatable polymer disc disposed on a hub within the cavity, wherein said rotatable polymer disc has projections distributed around its circumference such that rotation of the polymer disc delivers a fixed volume of fluid from the inlet channel to the outlet channel.

16. The device of claim 15, further including means for detecting the rotation of said polymer disc.

17. A device for controlling fluid flow in microchannels, comprising:

a first and a second intersecting microchannels, wherein said first microchannel includes two spaced apart retaining means;

a mobile monolithic polymer element disposed in said first microchannel and moveable between the retaining means to block fluid flow through said second microchannel; and

means for providing a displacing force to control the movement of said polymer element.

18. A device for controlling fluid flow in microchannels, comprising:

a plurality of microchannels converging at a common intersection,

wherein at least one of said plurality is a fluid inlet, and wherein the common intersection includes spaced apart retaining means and a mobile polymer monolith moveable between the retaining means to block fluid flow into one or more of said plurality of microchannels.

19. A method for shaping a monolithic polymer element disposed within a microchannel, comprising:

exposing the surface of the polymer element to radiation to remove a portion of the surface and thereby shape the polymer element; and

flushing the microchannel with a liquid to remove depolymerized material.

20. The method of claim 19, wherein the source of radiation is a laser.

21. The method of claim 20, wherein the laser is a frequency doubled Argon-ion laser operating at 257 nm.

22. A valve for controlling fluid flow in microchannels, comprising:

a plurality of microchannels in fluid communication with a central microchannel, wherein at least one of said plurality is a fluid inlet, and wherein the central microchannel includes spaced retaining means and a mobile polymer monolith moveable between the retaining means, wherein the polymer monolith, shaped by the method of claim 19, provides for diverting fluid from the fluid inlet and into one or more of the plurality of microchannels.

23. A method of making a mobile, monolith polymer element in a microchannel, comprising:

a) preparing a monomer mixture by mixing together 1,3-butanedioldiacrylate, tetrahydrofurfuryl acrylate, hexyl acrylate,

acryloyloxyethyltrimethylammonium methyl sulfate, and a photoinitiator;

b) preparing a solvent mixture by mixing together acetonitrile, methoxyethanol, and phosphate buffer;

c) mixing together the monomer and solvent mixtures in the ratio of about 60:40 by volume;

d) loading the combined mixture into a microchannel;

e) polymerizing the combined mixture by exposure to UV radiation; and.

f) flushing unreacted monomer from the microchannel.

24. A mobile monolithic polymer element disposed within a microchannel made by the method of claim 23.

25. A method of making a mobile monolithic polymer element in a microchannel, comprising:

a) preparing a monomer/solvent mixture by combining together

pentaerythritol triacrylate (PETRA),

hyroquinone monomethyl ether,

1-propanol, and

an amount of photo-initiator equal to about 0.5% of the weight of the PETRA;

b) injecting the monomer/solvent mixture into a microchannel; and

c) photopolymerizing the mixture.

26. The method of claim 25, wherein the photo-initiator is 2,2'-azobisisobutyronitrile.

27. A mobile monolithic polymer element disposed within a microchannel made by the method of claim 25.

28. A device for controlling fluid flow in a microchannel, comprising

a mobile monolithic polymer element disposed in the microchannel, wherein said polymer element is made by the method of either claim 23 or claim 25;

spaced apart retaining means disposed in the microchannel;

a bypass duct; and

means for applying a displacing force to the either end of the microchannel.

29. A device for controlling ionic current flow in a microchannel, comprising:

a mobile, monolithic polymer element disposed in the microchannel, wherein said mobile, monolithic polymer element is made by polymerizing a monomer mixture within the microchannel; and

means for providing a displacing force to control the movement of said polymer element in the microchannel.

30. A system for providing substantially continuous and unidirectional fluid flow through microchannels, comprising:

hydraulic pressure means having an inlet and outlet;

a microchannel connected to each of the inlet and the outlet; and

at least one check valve disposed in each microchannel, wherein said check valve comprises a mobile monolithic polymer element made by polymerizing a monomer mixture within the microchannel, spaced apart retaining means to restrict movement of the polymer element within the microchannel, and a bypass duct.

31. The system of claim 30, wherein said hydraulic pressure means comprises an electrokinetic pump.

32. The system of claim 30, wherein the mobile monolithic polymer is made

by the method of claim 5.

33. A system for providing a substantially continuous and unidirectional flow through microchannels to a chromatography column, comprising:

an electrokinetic pump having an inlet and outlet;

a microchannel connected to each of the inlet and the outlet, wherein each microchannel is joined at a common junction in fluid communication with a chromatography column; and

a check valve disposed in each microchannel, wherein said check valve comprises a mobile monolithic polymer element, spaced apart retaining means to restrict movement of the polymer element within the microchannel, and a bypass duct.

34. A check valve device for controlling fluid flow through microchannels such that an actuating fluid and test fluid are separate, comprising:

a chamber having a mobile polymer monolithic element disposed therein, wherein said chamber has opposed first and second ends, and wherein the mobile polymer monolith is made by polymerizing a monomer mixture within the microchannel;

an actuating fluid inlet channel joined to the first end to admit an actuating fluid to said chamber; and

a fluid flow inlet and a fluid flow outlet channel each joined to the second end.

35. A check valve device for controlling fluid flow through microchannels such that an actuating fluid and test fluid are separate, comprising:

a chamber having a mobile polymer monolithic element disposed therein, wherein said chamber has two arms arranged in a U-shape

configuration, and wherein the mobile polymer monolith is made by polymerizing a monomer mixture within said chamber;

an actuating microchannel fluid inlet joined to the terminus of one arm;

a microchannel fluid flow inlet and a microchannel fluid flow outlet each joined to the terminus of the second arm; and

an actuating microchannel fluid inlet joined to the end of said chamber opposite the terminations of the first and second arms.

36. A method for controlling fluid flow through microchannels, comprising:

providing a chamber having a mobile polymer monolithic element disposed therein, wherein said chamber has opposed first and second ends;

providing an actuating fluid inlet microchannel in fluid communication with the first end for admitting an actuating fluid to said chamber and a fluid flow inlet microchannel and a fluid flow outlet microchannel each joined to the second end;

admitting an actuating fluid into the chamber through the actuating fluid inlet microchannel to force the mobile polymer monolithic element against the second end of the chamber, thereby sealing the flow inlet and outlet microchannels to prevent fluid flow therebetween.

37. The method of claim 36, wherein the mobile polymer monolith is made by the method of claim 5.

38. A method for control of fluid flow through microchannels, comprising:

providing a substrate fabricated to define a microchannel system disposed thereon, the microchannel system, in part, comprising:

a chamber having a mobile polymer monolithic element disposed therein, wherein said chamber has opposed first and second ends;

an actuating fluid inlet channel joined to the first end to admit an actuating fluid to said chamber; and

a fluid flow inlet and a fluid flow outlet channel each joined to the second end.

39. The method of claim 38, wherein the polymer monolith is made by the process of claim 5.

40. The method of claim 7, wherein the monomer to solvent ratio is 60:40.